SENSOR SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a sensor system.

2. Description of the Related Art

A distance measurement sensor of the light projection triangulation type is available which directs pulsed light to an object to be measured and in which a light receiver portion is located at a given base line length from a light projector portion and light reflected from the object is received by the light receiver portion, and the distance to the object to be measured is determined. If this sensor is operated at a high speed continuously, a large amount of electrical power is consumed.

A conceivable method of reducing the power consumed by such sensor is illustrated in Fig. 4, where a general-purpose controller is added to the sensor. This controller controls the operation of the sensor such that it operates slowly and intermittently.

The configuration shown in Fig. 4 is briefly described. The general-purpose controller (hereinafter referred to as CNT) is indicated by numeral 100 and uses a battery E as a power supply and is connected with a distance measurement module (DMM) 200 via terminals T_1-T_8 and controls the operation

of the distance measurement module 200 via these terminals. Let Tp, P_1, P_2, and P_3 be output signals appearing at terminals Tp, P_1, P_2, and P_3, respectively, shown in Fig. 4.

The CNT 100 is now described. The CNT 100 has a low power-consumption power-supply regulator circuit (hereinafter referred to as REG) 103 for providing a low power-consumption power source V_{reg1} to a low power-consumption timer circuit (hereinafter referred to as RTC) 101 and to a CPU 102. A power-supply circuit (REG) 104 provides a power source V_{reg2} used as a power source to the DMM 200. The RTC 101 intermittently supplies a trigger signal Tp to the CPU 102, which in turn is triggered by the trigger signal Tp and operates in a given manner. Normally, the CPU 102 is in a standby mode in which the CPU consumes only quite a small amount of electrical power. When the signal P_1 from the CPU 102 is ON, the power-supply circuit (REG) 104 generates voltage V_{reg2}. When the signal P_1 is OFF, the power-supply circuit (REG) 104 is in a standby mode in which the circuit consumes only a quite small amount of electrical power. The output signal P_2 from the CPU 102 turns on or off the switch SW_1. When the signal P_2 is ON, the switch SW_1 permits supply of a voltage to the DMM 200. A resistor R_1 and a capacitor C_2 together form a power-supply filter circuit 105 for a distance measurement IC (hereinafter referred to as DMIC) 201. Where the time constant is set large and a large current flows through an IRED (infrared-emitting diode) 202,

the filter circuit 105 suppresses variations in the electrical power through the DMIC 201. Also shown are a capacitor C_1 and a resistor R_4.

The DMM 200 is made up of the DMIC 201, the IRED 202, a PSD (position-sensitive detector) 203, resistors R_2, R_3, transistors Tr_1, Tr_2, a capacitor C_c, and so on, and operates as a distance measurement sensor. This sensor has an output terminal at which a signal indicating the result of a distance measurement appears. This output terminal is the collector of the transistor Tr_2. That is, the output terminal for producing a signal indicating the result of a distance measurement is the output terminal of open collector type.

The operation is next described briefly by referring to Fig. 5, where Tp, P_1, V_{reg2}, P_2, Vd, P_3, Ir_0, Data, and O_1 indicate voltage waveforms at terminals Tp, P_1, V_{reg2}, P_2, Vd, P_3, IR_0, Data, and O_1, respectively, shown in Fig. 4. In Fig. 5, IR_4 indicates the waveform of current at a terminal IR_4 shown in Fig. 4. In Fig. 5, CPU indicates the relation between the operation of the CPU shown in Fig. 4 and its standby mode.

The RTC 101 produces the trigger signal Tp at intervals of t_{00} time. In response to this, the CPU 102 turns on the signal P_1 for a period of t_{10} time and operates the REG 104. After a lapse of t_{20} time, the operation of the power-supply circuit 104 stabilizes. Then, the signal P_2 is turned on, thus turning on the switch SW_1. The output voltage V_{reg2} from

the REG 104 is supplied to the filter circuit 105, whose output voltage Vd is applied as electrical power to the DMM 200.

In response to the signal P_2 being turned on, electrical power is supplied to the DMIC 201 within the DMIC 200. Then, the CPU 102 waits for a period of t_{30} time to stabilize the DMIC 201. The CPU 102 turns on the operating signal P_3 for a period of t_{40} time, thus causing the DMM 200 to start an operation for a distance measurement.

In response to the application of the operating signal P_3 that is in an ON state, the DMIC 201 produces an emission signal IR_0 to operate the IRED 202 to perform a measurement of a distance. The result is reflected in the state (i.e., ON or OFF) of the transistor Tr_2. The result is sent to the CPU 102 from the collector terminal of the transistor Tr_2. In particular, if an object to be measured is detected, the transistor Tr_2 is turned on, causing the terminal T_8 to assume state 0. If no object to be measured is detected, the transistor Tr_2 is turned off, making the terminal T_8 assume state 1. When the ON state of the signal P_3 ends, the CPU 102 turns off the signals P_1 and P_2 and returns to the standby mode.

In this way, the CNT 100 controls the operation of the DMM 200 to make intermittent the distance measurement operation of the DMM 200.

In the distance measurement sensor as described above, the capacitor C_c or the like is connected with the distance

measurement IC (DMIC) 201 to generate a given frequency. A timing signal for the distance measurement operation is created according to the generated frequency. Therefore, depending on the specifications of the distance measurement sensor, the pulse width of the light emitted from the IRED 202 may be increased. For this purpose, this operating frequency f_0 may be lowered. That is, the time taken to project light has some interval of time.

Where this is taken into consideration, in order to assure that data obtained by a measurement of a distance is accepted into the CPU 102 by operating the DMM 200 intermittently, the supply of electrical power to the DMM 200 should not be interrupted during the measurement operation, even if the operating speed of the DMM 200 is low and a long time is taken to emit light.

To solve the aforementioned problem, it is necessary to set the time between the instant when the DMM 200 starts an operation for a distance measurement operation and the instant when the power supply is turned off, i.e., the period of the ON state of the signal P_3, be set so long that no troubles take place if the operating frequency f_0 is lowest. In this case, an allowance is given, and the possibility of occurrence of malfunctions decreases accordingly. However, the amount of wasteful power consumption increases.

In another method, an adjusting means is fitted to the

CNT 100. According to the specifications of the DMM 200, the timing at which the CNT 100 accepts measurement data is slowed or the time for which electrical power is supplied to the sensor is set sufficiently long. In this way, an adjustment is necessary. That is, in this case, the CNT 100 must be adjusted according to the actually used operating timing of the DMM 200. If a general-purpose product is used as the CNT 100, each individual product needs adjustments. Furthermore, if the CNT 100 is managed by adjusting it, the operating frequency f_0 varies due to variations in capacitance among the individual products used as the capacitor C_c, temperature variations, and variations in characteristics among the individual products used as the DMIC 201. To cope with variations in the time taken to emit light due to variations in the operating frequency f_0 as described above, it is necessary to set the period of the ON state of the signal P_3 at a sufficiently long time, even if cumbersome operations such as adjustments are performed. As a result, a voltage is kept applied to the DMIC 201 in spite of the fact that the distance measurement operation has already ended in practice. Hence, electrical power continues to be wasted.

This drawback is described by referring to Figs. 6(a) and 6(b). Fig. 6(a) illustrates the operation when the operating frequency f_0 is high. Fig. 6(b) illustrates the operation when the operating frequency f_0 is low. The time

between the leading edge of the signal P_3 and the latching time L is set constant and sufficiently long ($tL0 = tL0'$, $t_{30} = t_{30}'$, $t_{40} = t_{40}'$) so that data can be latched at L even if the operating frequency f_0 varies. After being read into the CPU 102 and processed, data is delivered from the output terminal O_1. Then, the signals P_2 and P_3 are turned off to stop the supply of electrical power. Also, the CPU 102 itself makes a transition from the operation mode to the standby mode. That is, even after the distance measurement operation ends and data derived from the measurement is delivered, a voltage is kept applied to the DMIC 201. In consequence, wasteful power consumption continues.

This problem is not limited to a light projector-type distance measurement sensor. Rather, this problem arises with every sensor means that performs a desired measurement and then produces an output signal corresponding to the results of the measurement. That is, where the time taken to perform a given measurement has some interval of time, electrical power is supplied for a time sufficient to accommodate the interval. This method produces the aforementioned problem.

Many sensors use the open collector output (Tr_2) to send data even to a system using a different voltage or to permit a relay or the like to be directly activated. In this scheme, a pull-up resistor R_4 is coupled to the electrical power V_{reg1} for the CPU 102 to accept data.

This DMM 200 judges whether there is an object to be measured or not. If an object to be measured is detected, the transistor Tr_2 that is normally OFF is kept ON. In this configuration, current is kept supplied to the pull-up resistor R_4 from the power source V_{reg1} during the period t_{50} between the instant when the signal Tr_2 is turned on and the instant when the signal P_3 is turned off and during the period t_{60} between the instant when the period t_{50} ends and the instant when the voltage Vd reaches the cutoff voltage Vth of the distance measurement IC (DMIC) 201, as shown in Fig. 5, for the following reason. Even if the power to the distance measurement module 200 is cut off, the voltage Vd applied to the DMIC 201 does not quickly drop to zero because of electric charge stored in the capacitor C_2. Rather, the voltage gradually decreases to the cutoff voltage of DMIC 201 because of power consumption by DMM 200. Therefore, the power consumption at the resistor R_4 hinders lower power consumption. If the voltage Vd further drops to the cutoff voltage Vth, the state is often maintained for a relatively short time (from on the order of seconds to on the order of minutes). If power is then supplied, the transistor Tr_2 may be kept in conduction. Current starts to flow into the pull-up resistor from the application of the power during a period of t_{70} time. Such a current is important to a low power-consumption sensor. This hinders reducing the power consumption.

SUMMARY OF THE INVENTION

The present invention provides a sensor system having a sensor and a controller for controlling the supply of electrical power to the sensor. The controller accepts the output signal from the sensor and performs desired processing. The controller includes a power-supply switch for switching on and off the supply of electrical power to the sensor and a control circuit for turning off the power-supply switch in response to acceptance of the output from the sensor. This assures that the output from the sensor is accepted. Furthermore, power consumption can be curtailed. Therefore, the problems with the prior art construction can be reduced. In the past, electrical power has been wasted to assure acceptance of the output from the sensor, or the power application time has been set short to reduce wasteful power consumption, which would have made it impossible to accept the sensor output.

Where the aforementioned sensor is a distance measurement sensor comprising a light projector means, a driver circuit for supplying an emission signal to the projector means, and a light-receiving means for receiving light arising from the projection of light from the light projector means, if the controller described above initiates acceptance of the output from the sensor in response to the emission signal, the same advantages can be obtained as the foregoing. Furthermore, the emission signal can be used for light projection and for

the start of acceptance, thus simplifying the structure compared with the structure in which signals for the light projection and for the start of acceptance, respectively, are produced.

The electric current wasted by resistors can be reduced further by the following configuration. The sensor described above has an open collector type output terminal producing the aforementioned output. The controller described above further includes a series combination of a resistor and a switching means. The series combination is connected between the output terminal described above and a power supply. A voltage developed at a junction terminal of the resistor and the output terminal is accepted as the output from the sensor. The control circuit turns on or off the switching means according to the emission signal.

Where the controller assumes a standby state in which the power consumption is low, in response to the end of the desired processing, the same advantages as the foregoing can be had. Furthermore, the controller achieves further reduction of power consumption.

Other objects and features of the invention will apparent in the course of the description thereof, which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a circuit block diagram of a sensor system in accordance with the present invention;

Fig. 2 is a timing chart illustrating the operation of the sensor system shown in Fig. 1;

Fig. 3 is a timing chart illustrating the operation of the sensor system shown in Fig. 1;

Fig. 4 is a circuit block diagram of the prior art sensor system;

Fig. 5 is a timing chart illustrating the operation of the prior art sensor system shown in Fig. 4; and

Fig. 6 is a timing chart illustrating the operation of the prior art sensor system shown in Fig. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Details of the present invention are hereinafter described in relation to one embodiment illustrated in the accompanying drawings. A distance measurement sensor (distance measurement module) is taken as an example of the sensor. The sensor is not limited to this. Any sensor for detecting or measuring an object of interest may also be used as the sensor.

Fig. 1 is a circuit block diagram of a sensor system in accordance with the invention. Figs. 2 and 3 are timing diagrams illustrating the operation. Note that like components are indicated by like reference numerals in both Figs. 1 and 4.

Referring to Fig. 1, a controller (hereinafter referred to as CNT) 1 acts as a control means and uses a battery E

as its power supply. The controller 1 is connected with a distance measurement module (hereinafter referred to as DMM) 2 via terminals T_1-T_{10}, and controls the operation of the DMM 2 via these terminals. A series circuit 106 consists of a series combination of a so-called pull-up resistor R_4 and a switching means SW_2, and is connected between a low power-consumption power source V_{reg1} from a REG 103 and the output terminal T_8 (open collector type output terminal) of the distance measurement DMM 2 connected via the terminal T_7. An emission signal IR_0 for the (infrared-emitting diode) IRED 202 is applied to the base of the transistor Tr_3 via the resistor R_5. The collector of the transistor Tr_3 is connected with the power source V_{reg1} of the REG 103 via the resistor R_6. A junction terminal T_{11} between the collector of the transistor Tr_3 and the resistor R_6 is connected with the CPU 102.

The operation is described by referring to Fig. 2. Note that like waveforms are indicated by like reference numerals in both Figs. 2 and 4. In Fig. 2, O_2 and P_4 indicate voltage waveforms at the terminals O_2 and P_4, respectively, shown in Fig. 1.

The RTC 101 produces the trigger signal Tp at intervals of t_0 (e.g., 0.5 second). In response to this, the CPU 102 turns on the signal P_1 to operate the REG 104. After a lapse of t_2, the operation of the REG 104 stabilizes. Then the

signal P_2 is turned on, thus turning on the switch SW_1. The voltage V_{reg2} from the REG 104 is applied to the filter circuit 105. Its output voltage Vd is supplied as electrical power to the DMIC 201. The operation is the same as the operation of the prior art structure shown in Fig. 4 up to this point.

After electrical power is supplied to the DMIC 201 in response to ON state of the signal P_2, the CPU 102 waits for a period of t_3, i.e., until the operation of the DMIC 201 stabilizes. Then, the operating signal P_3 is turned on to start an operation for a measurement of a distance using the DMM 2. In the present embodiment, the ON time of this operating signal P_3 is not previously set on the side of the CNT 1. Rather, the ON time is adjusted according to the operation of the DMM 2. Hence, the amount of electrical power wasted is reduced compared with the prior art technique. This operation will be described later.

The DMIC 201 in the DMM 2 produces the emission signal IR_0 in response to application of the operating signal P_3 in an ON state. This operates the infrared-emitting diode (IRED) 202 to perform a measurement of a distance. Specifically, the IRED 202 is made to emit light a given number of times (two times in the present example). Light reflected from an object to be measured is received by the PSD 203. The output from the PSD 203 is arithmetically processed to detect the distance. In response to information including the detected

distance value and the presence or absence of an object judged from the distance value, the transistor Tr_2 is turned on or off. A signal indicating this information about the distance and the presence or absence is made to appear at the terminal T_8. In the present example, where an object is detected, the transistor Tr_2 is turned on. Where no object is detected, the transistor Tr_2 is turned off.

The emission signal IR_0 produced from the IRED 202 while the DMM 2 is performing a measurement of a distance is inverted in level by the resistor R_5, the transistor Tr_3, and the resistor R_6, producing an inverted signal Iri to the CPU 102. The emission signal IR_0 is normally a relatively short pulse of approximately microseconds to tens of microseconds and so the increase in the average current consumption due to the level inversion is slight.

The CPU 102 detects the end of the light projection operation of the IRED 202 by making use of the inverted signal Iri. In the present embodiment, it is assumed that the emission operation is ended when the IRED 202 emits light twice. The end of the emission operation is detected by detecting the trailing edge of the second pulse of the emission signal IR_0. The number of emissions is not limited to two. The number may be modified properly.

On detection of the end of the light projection, the CPU 102 judges that information indicating the presence or

absence of an object is produced from the DMM 2. To permit the information to be read, the CPU 102 immediately turns on the signal P_4. This turns on the switch SW_2. Therefore, the pull-up resistor 4 is connected with the collector of the transistor Tr_2. A signal produced at the terminal T_8 and coming from the DMM 2 can be read via the terminal *Data*. That is, the terminal T_8 is coupled to the voltage V_{reg1} via the pull-up resistor 4. Consequently, the voltage at the terminal *Data* assumes level 1 or 0, depending on whether the transistor Tr_2 is ON or OFF. The CPU 102 can read this as a binary-coded signal and accept it.

After a lapse of the period (several microseconds to several tens of microseconds in practice) beginning with the end of the light projection from the IRED 202 and ending with production of information indicating the presence or absence of an object since the CPU 102 has turned on the signal P_4, the signal appearing at the terminal *Data* and carrying information indicating the presence or absence of an object is latched, or accepted, in the DMIC 201. If the rising portion of the voltage waveform is distorted due to the ON resistance of the switch SW_2 or capacitance when the signal P_4 is turned on to connect the resistor R_4, the CPU may wait for a time (several microseconds at the longest) longer than normal until the voltage becomes constant since the signal P_4 has been turned on. In this way, the information is accepted after sensing

that a signal carrying information indicating the presence or absence of an object appears at the terminal *Data* and so the time between the instant when the information is produced and the instant when the information is accepted can be controlled. Therefore, the aforementioned time between the instant when a signal carrying information indicating the presence or absence of an object appears at the terminal *Data* and the instant when the information is read is prevented from becoming long wastefully. That is, the wasteful wait time can be reduced.

Immediately after accepting the information from the DMM 2 as described above, the CPU 102 turns off the signal P_4, turning off the switch SW_2. This disconnects the resistor R_4. The signals P_2, P_1, and P_3 are then turned off. The supply of electrical power to the DMM 2 is cut off. As a result, the ON time of the signal P_3 becomes shorter than conventional. The current iR_4 flowing into the resistor R_4 is quite slight on average.

Since the CNT 1 (control circuit) turns off the power-supply switch SW_1 in response to the acceptance of the output from the DMM2 (sensor means) in this way, it is assured that the output from the DMM2 is accepted. Furthermore, electrical power can be saved. Consequently, the sensor system in accordance with the present invention is free from the problems which would have occurred with the prior art sensor system. That is, in the prior art sensor system, supply of

electrical power is continued in spite of the end of the operation of a sensor to assure reading of a signal from the sensor means, resulting in a wastage of power. Where the supply of electrical power to the sensor means is cut off while the sensor means is in operation in an attempt to reduce wasteful power consumption, it will be impossible to read the output from the sensor means.

After sensing that a signal indicating the presence or absence of an object appears at the terminal *Data*, the signal is accepted. Immediately after the end of the acceptance, the supply of electrical power to the DMM 2 is cut off. Therefore, the time between the instant when the signal indicating the presence or absence of an object is produced to the terminal *Data* and the instant when the signal is accepted is prevented from becoming wastefully long; otherwise, power would be wasted.

Since the emission signal Ir_0 for the IRED 202 (light projection means) is used to control the timing at which the output signal from the DMM 2 is accepted. Therefore, the structure can be simplified. That is, it is not necessary to produce two signals used for projection of light and for start of acceptance of the output signal, respectively; otherwise, the structure would be complicated.

Where the DMM2 (sensor means) for producing a signal indicating the presence or absence of an object through the open collector type output terminal T_8 is used, the series

combination 106 of the resistor R_4 and the switch SW_2 (switching means) is connected between the output terminal T_8 and the power source V_{reg1}. A voltage developed at the terminal T_{11} between the resistor R_4 and the output terminal T_8 is accepted as the output from the DMM2 (sensor means). The switch SW_2 (switching means) is turned on or off in response to the generation of the emission signal Ir_0 for the IRED 202. Therefore, when a signal carrying information is not produced from the output terminal T_8, the amount of power wasted by the resistor R_4 can be decreased. Furthermore, the emission signal Ir_0 for emission of the IRED 202 is used to turn on or off the switch SW_2, thus enabling simplification of the configuration. That is, it is not necessary to produce two output signals used for projection of light and for controlling the switch SW_2, respectively; otherwise, the configuration would be complicated.

The CPU 102 performs processing for modifying the accepted signal carrying information to a given output form. The processed signal is delivered from the output terminals O_1, O_2, etc. For example, a signal obtained by inverting the level of the signal at the terminal *Data* or a coded signal is delivered.

The power supply to the DMM2 (sensor means) is cut off, and then the CPU 102 performs the remaining processing. This further reduces the amount of current consumed by the DMM2 (sensor means). That is, the amount of power wasted by the

DMM2 (sensor means) can be reduced.

If signals are produced from the output terminals O_1, O_2, etc., the CNT 1 returns to its initial state. The mode of operation is switched to the standby mode of low power consumption. Consequently, further power savings can be achieved at the controller 1 (control means).

In Fig. 2, no object is detected during period TA. At instant B, information carried by the signal appearing at the terminal *Data* is latched.

During period TB, a signal indicating a state different from the state of the terminal O_1 is produced to the terminal O_2.

During period TC, the DMM2 keeps detecting an object. The state at the terminal *Data* is 0. Since the signal P_4 is turned ON only for a short period around the data latch, the average amount of current consumed by the resistor R_4 is smaller than heretofore.

Fig. 3 shows the operation where the operating frequency f_0 of the DMIC 201 is varied. Fig. 3, (c), illustrates the operation where the operating frequency f_0 is high. Fig. 3, (d), illustrates the operation where the operating frequency f_0 is low. In the present embodiment, the timing at which data is latched is varied in response to the emission signal IR_0 that varies in response to variations in the operating frequency f_0 as mentioned previously. That is, the timing

at which data is latched varies in response to variations in the operating frequency f_0 ($tL < tL'$, $t_3 = t_3'$, and $t_4 < t_4'$). Therefore, the operating frequency f_0 can be set regardless of the time for which power is supplied to the DMM 2. Furthermore, power consumption savings are achieved because the signal P_2 is turned off to cut off the supply of power to the distance measurement sensor immediately after latching data.

In addition, it is not necessary to adjust controller CNT 1 according to the rated operating speed of the DMM2 while saving power consumption. This improves the generality of the controller CNT 1.

If the distance measurement IC 201 can deliver a signal indicating the completion of a measurement of a distance or a signal (Ed in Fig. 1) confirming data, this signal is detected by the CPU 102 instead of Ir_0. The resulting signal may be used for latching of data or for control of the operation of the signals P_2 and P_4.

The switch S_1 is provided as a function-setting switch and used to change the measurement interval or the like. Although only one switch S_1 is shown, plural switches may also be used.

The present invention provides a sensor system having a sensor and a controller for controlling the supply of power to the sensor. The controller accepts the output from the

sensor and performs desired processing. This sensor system is characterized in that the controller includes a power-supply switch for switching on or off the supply of power to the sensor and a control circuit for turning off the power-supply switch in response to acceptance of the output from the sensor. This assures that the output from the sensor is accepted. Furthermore, power consumption savings can be accomplished. In the past, electrical power has been wasted to assure acceptance of the sensor means output, or power consumption decrease has made it impossible to accept the output from the sensor. The sensor system according to the present invention is free of these problems.

Where the sensor consists of a distance measurement sensor having a light projection means, a driver circuit for supplying an emission signal to the light projection means, and a light-receiving means for receiving light arising from projection of light from the light projection means, if the controller starts acceptance of the output from the sensor in response to the emission signal, the same advantages can be produced as the foregoing. Furthermore, the emission signal can be used for both light projection and the start of acceptance, thus simplifying the structure.

In another embodiment of the invention, the sensor includes an open collector type output terminal producing the output described above. The aforementioned controller further

includes a series combination of a resistor and a switching means. The series combination is connected between the output terminal described above and a power supply. A voltage developed at the terminal between the resistor and the output terminal is accepted as the output from the sensor. The control circuit turns on or off the switching means according to the emission signal. This structure can reduce the amount of current wasted by the resistor.

Where the controller described above is placed in the standby state of low power consumption in response to the end of the desired processing, the same advantages as the foregoing can be gained. Additionally, the controller can reduce power consumption further.